Information Sciences Letters

Volume 12
Issue 6 *Jun. 2023*

Article 35

2023

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Information Sciences Letters
An International Journal

http://dx.doi.org/10.18576/isl/120635

A Statistical Learning Approach to Evidence the Acoustic Miracles in the Holy Quran Using Audio Features

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Received: 21 Feb. 2023, Revised: 22 Mar. 2023, Accepted: 24 Mar. 2023.
Published online: 1 Jun. 2023.

Abstract: This paper presents a novel approach for exploring the intrinsic acoustic properties of the Holy Quran, in an attempt to provide yet one more evidence of the miraculous nature of the Quran. The study uses a dataset composed of recitations made by seven prominent reciters and three chapters of the Quran. A novel statistical approach is used to detect the correlation between the recitations of the reciters for three different Chapters (Quranic Surah). The study utilizes the Mel-Frequency Cepstral Coefficients (MFCCs) feature to detect certain common patterns among the recitations. The main measurement indexes used in this study are the correlation and the Euclidian Distance (ED) between the mean of the MFCCs Cepstral Coefficients, and deltadelta MFCCs. The study reveals a strong correlation and short distance between all recitations for one verse at a time, and relatively high correlation and short distance for two or more verses. Furthermore, the study lays down a foundation to detect and formulate acoustic clusters for sequential verses in the Holy Quran.

Keywords: Acoustic Quran Miracles, Audio Features, Correlation Coefficients, Euclidean Distance, MFCCs.

1 Introduction

The truthfulness of Muhammad ﷺ message is established based on the holy Quran [1]. Holy Quran [2] is the holy book of the Islamic religion. From year 610, the holy Quran was and still a subject matter for many investigators around the world; it had provoked many researchers to analyze its miraculous nature in different fields such as scientific, rhetorical, linguistic, acoustic and style [3]. Holy Quran contains 114 chapters (surah); chapters are classified as either Meccan (revealed in the city of Mecca) or Medinan (revealed in the city of Medina). Each chapter is comprised of a different number of verses; each verse has many characteristics which carry certain impact depending on its lexical, syntax structure or semantics.

The acoustic features of a verse depend on the wording of each verse in the holy Quran words itself, word meaning and diacritics (pronunciations, punctuations, and accents). Each word in the holy Quran is claimed to be placed in its rightful place which may not be placed anywhere else and there are no other words (with similar meaning) which can replace it, to provide the same impact. The holy Quran has a mechanism to read named Tajweed [4]. Reciters must follow the Tajweed rules. The wording of the verses in the Quran are claimed to be responsible for the beautiful recitations, irrespective of the reciter's language, accent, knowledge of the Arabic language, or even the meanings of the Quran [3], which leads to one of the miraculous features of the Quranic linguistic structure.

In this paper, we provide a novel statistical approach to prove the claimed acoustic miracles in the holy Quran using audio features, where the holy Quran verses are read by different reciters [5]. Each recitation of verses has many pitch characteristics which can be detected from their audio files using audio feature extraction analysis. Each audio has specific features, which depend on time, frequency, and amplitude. One of the main objectives of this study is to show that there exists a common pattern, which appears in the audio files, irrespective of who the reciter is. The method used in this study for feature extraction is Mel-frequency cepstral coefficients (MFCCs) [6]. There are other methods, which we have used for analysis of the results, but based on our observations, we find that MFCCs is the most comprehensive feature, which encompasses the three main characteristics of an audio, namely time, frequency and amplitude [7].

To detect unique common patterns among all investigated recitations, we used two different measures, namely correlation coefficients and the Euclidean distance [8].

The proposed model is tested against three chapters, namely Qaf (Surah #50), Al-Najm (Surah # 53) and Al-Falaq (Surah

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#113) and seven reciters using Hafs An Asim narration [9].

In the final results, this work is sought to provide one more proof to the miraculous structure of the holy Quran, namely the acoustic miracles using audio features.

The remainder of this paper is organized as follows: Section two describes the related work. Section three describes the methodology of the proposed system. Section four presents the results. In section five the conclusion will present the most important findings from the topic under research and future work.

2 Related Work

In this section, we review the related work of several rhetorical, historical and descriptive studies, which have addressed the acoustic miracles in the holy Quran. We also review several works in speech recognition in the holy Quran. We examine other important studies related to the complexity of holy Quran recitation audio feature extraction and methods used for similarity between audios.

Muhammad [10] studied one of Quranic phonetic phenomena and the phonetic meaning of the Quranic verses. Its rhetorical study showed harmony among graphic image and the sound that illustrate the rhythmic image of Quran verses. In [11], the authors made a descriptive study to investigate the acoustic miracles in the Holy Quran using Tajweed rules and performance of recitation. They discussed the target of the rules of Al-Tajweed in the holy Quran and its association of acoustic rhythm and discussed the importance of acoustic miracles compared to other Holy Quran miracle types. As a result, the acoustic rhythm of holy Quran shaped the artistic image of verse, where the smallest sound unit in the Holy Quran can represent a research material. Intonation has two functions, a performative function and a semantic function, and mastering intonation and knowing it is very important because it is related to the meaning of verse.

In [12], the authors used two methods (historical and descriptive) to evidence the acoustic miracles in chapter#37 Al-Safat. The study concluded that the Quranic style is a high style in its form and content, so there is no way to compare it with human speech. The acoustic rhythm relates to vocal retraction, repetition, Quran comma and Quran verse cluster. Intonation in holy Quran is not just limited to pitch loudness; but it is a complex set of performance indexes (the voice, with its accents and commas).

D. Blqasem [13], presented some evidence of the holy Quran acoustic miracles. One can feel the acoustic rhythm while listening to the Quran recitation or by reading it, especially when reciters follow Tajweed rules. All this appears because of the acoustic miracles in the Holy Quran. The authors represent images of this acoustic miracle, such as the types of break rules that the reciters must follow while reading verses from the holy Quran.

The voice vocal balance during recitation constitutes an element of beauty tool to catch the listener. The authors affirmed that the holy Quran is characterized by a strong influence on humans by acoustic rhythm of holy Quran recitation, which has deep impact on the heart and mind. The authors in [13] and [14] made a descriptive study to prove the acoustic miracles in the holy Quran.

MM Al Anazi [15] proposed a machine learning model to identify the reciter of holy Quran. The extracted features were analyzed by Mel-frequency cepstral coefficients (MFCCs) and classified by the artificial neural network (ANN) and the k-nearest neighbor (KNN) classifiers for identifying the reciter of holy Quran. Their system used two chapters of the holy Quran, chapter 7 and chapter 32. They concluded that the ANN is a preferred machine learning algorithm for the proposed system where ANN offered 98.5% accuracy for chapter 7 and 97.2% accuracy for chapter 32. For KNN, the accuracy for chapter 7 is 97.02% and for chapter 32 is 96.07%.

Alkhateeb et. al., [16] also developed a machine learning approach for recognizing the reciter of the holy Quran. They used Mel Frequency Cepstral Coefficients for features extraction for holy Quran verses. Both the K-nearest neighbor (KNN) classifier and the artificial neural network (ANN) are used on the proposed approach. They select chapter #18 (Al-Kahaf) and chapter #36 (Yaseen) of the holy Quran to develop their system. The accuracy using the KNN for chapter #18 is 97.03% and chapter #36 is 96.08%. In ANN, 96.7% accuracy for chapter#36 and 97.62% accuracy for chapter#18.

Ghori [17], proposed web-based application that helped people to recite verses of holy Quran in a correct way and help them to make it a habit. They used Mel frequency cepstral coefficients (MFCC) and deep neural networks. Each single word in a recited verse is identified in the proposed system. They used the first and the last 19 chapters of the Holy Quran words (362 unique words).

Jalil et. al., [18], introduced a methodological tool to employ Systematic Literature Review with adaptation of Systematic Reviews and Meta-Analyzes (PRISMA) technique. As a result of their studies, they classified acoustical elements of the Quran into three major patterns, verbal element in the holy Quran, the Correlation between the meaning of the holy Quran words and its verbal analysis on the arrangement, rhyme and recurrence at the end of verses.

Muhammad [19], developed intelligent system named (E-Hafiz), to help Muslims in recitation and memorization of holy Quran verses. In [10], E-Hafiz has been improved. E-Hafiz aims to train learners how to recite verses by Tajweed rules and memorize the holy Quran in their hearts. Mel-Frequency Cepstral Coefficient (MFCC) technique used as feature extraction for learners recorded voices. The results are used to compare learners' recitation with expert reciters recitation files stored in database.

Al-Ayyoub and co-authors [20] improved deep learning techniques to identify the correct usage of Al-Tajweed rules in the holy Quran verses. They used several audio feature extraction techniques, such as Linear predictive Code (LPC), Mel-Frequency Cepstral Coefficient (MFCC), Wavelet Packet Decomposition (WPD) and Markov Model based Spectral Peak Location (HMM-SPL). For classification process he relied on k-Nearest Neighbors (KNN), Support Vector Machines (SVM), and Random Forest (RF). Their dataset contains 3,071 audio files of recitation by different reciters of both genders. Their study improved the classification accuracy to surpass 97.7%.

Also, in [20, 21, 22, 23], and system j-QAF [24] the authors used MFCC for feature extraction for holy Quran verses in several contribution.

Wang et al. [25] introduced new voice activity detection system based on MFCC similarity. They calculate MFCC Euclidean and MFCC correlation coefficient for each frame.

We notice that existing studies to evidence the acoustic miracles are limited to descriptive studies (focus on semantic and syntax) and verses meaning. Finally, there has been very limited efforts invested in using audio features as a scientific technique. Our work comes as a serious attempt to prove the acoustic miracles in holy Quran using audio features techniques.

3 Methodologies

This study used some tools and materials for data construction, and audio analysis. We developed the proposed study using Colab Python 3.7.14 and Audacity 3.1.3. The methodology pursued in this study consists of five essential phases as shown in Figure 1.

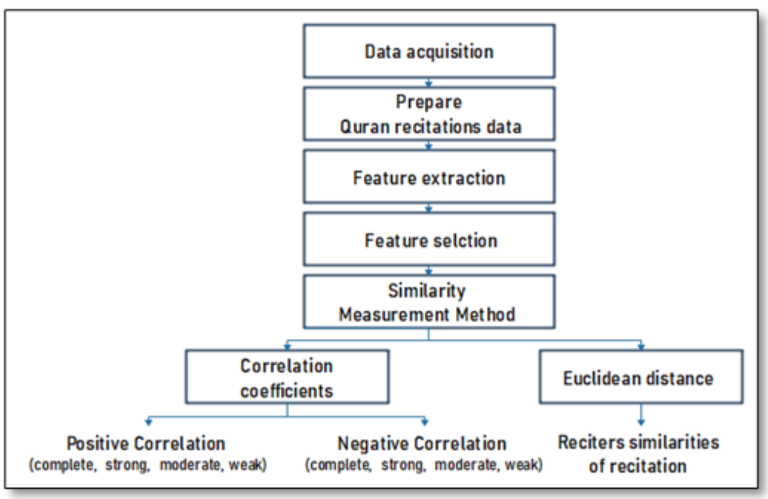


Fig. 1: The flow diagram of the proposed method.

3.1 Data Acquisition

The holy Quran recitations audios dataset is constructed by extracting audios recitations for seven of the most popular reciters; all holy Quran recitations audios are selected with Tajweed rules based on the narration of Hafs An Asim. The seven selected reciters are shown in Table 1.

Table 1: Reciters Information.

No.	Reciter name	Country	Born
1	Abu Bakr Ashaatree	KSA	1970
2	Abdurrahman AlSudais	KSA	1960
3	Saad AlGhamadi	KSA	1967
4	AbdulBasit AbdulSamad	Egypt	1927
5	Maher AlMuaiqly	KSA	1969

6	Mahmoud Al-Husary	Egypt	1917
7	Meshari Al-Afaasy	Kuwait	1976

For each of the reciters, we selected three chapters (Surah) of holy Quran, from the Meccan period revelation (first 13 years of the Message of Muhammad) The chapters' details are shown in Table 2. The chapters were selected carefully based on the characteristic of loudness, the semantic solidity and length of verses. The acoustic rhythm of holy Quran is most likely revealed when the verses are short, and the chapter has short breaks between verses. In long verses, it may disappear entirely, or slightly appear [25].

Table 2: Details of the three chapters

Chapter of the Quran	Type of chapter	Chapter number	Number of verses
Qaf	Makkan surah	50	45
Al Najm	Makkan surah	53	62
Al Falaq	Makkan surah	113	5

Chapter Qaf is a Makkan surah, which consists of 45 verses. The Surah begins with the letter Qaf, which is a whole verse by itself. The "mysterious character Qaf", repeats 57 times in the rest of the chapter. The concepts which Surah Qaf deals with are resurrection, the day of Judgement, paradise and hell, and affirm the oneness of Allah almighty and his Godship. The acoustic rhythm in Qaf chapter most likely is attributed to its acoustic features. Whisper, loudness, strength and looseness are some of the main word utterance characteristics in Qaf chapter [26].

Chapter Alfalaq is also Makkan; it consists of 5 verses. The concepts which Alfalaq chapter deals with is asking Allah for protection from the evil. The acoustic rhythm in Alfalaq chapter can also be attributed to its lexical structure in addition to its content. The main characteristic in the Alfalaq chapter verses are loudness and strength [27].

Al-Najm chapter started by swearing with the star, and the concepts, which Al-Najm deals with include the truthfulness of Muhammad message. The main characteristic in the Al-Najm chapter verses are loudness and strength [28].

We collected the audios of recitations using free certified holy Quran websites [29, 30]. We made sure that all the audio files are clear. The holy Quran recitations audios dataset constructed in this study will be expanded into a unique holy Quran reciters audios corpus to be shared with the research community. All verses recitations in this dataset are contained in 785 audio files.

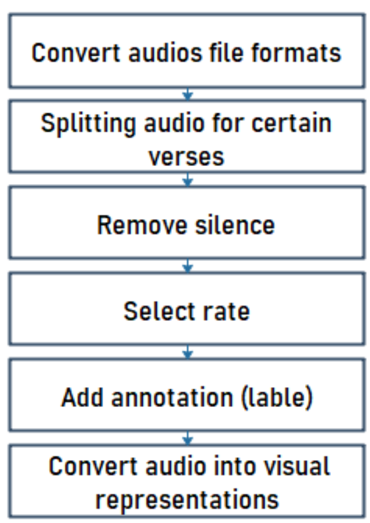


Fig. 2: Pre-Processing Steps

3.2 Prepare the Quran Recitations Audio Data

In preparing data, we make certain that all the verses audios in narrative of Hafs An Asim; this is to exclude variations, which may exist due to difference in narrations and recitation style. All pre-processing steps are shows in Figure 2.

1. Convert Audios File Formats

Audios are unstructured data like texts and images. They are stored in various file formats. In audio analysis it is recommended to use uncompressed file format as they don't omit any signal audio features, which may exist in the holy Quran recitations [31]. Holy Quran recitations audios are converted from mp3 file (MPEG-1 Audio Layer 3) format to

WAV (Waveform Audio File) format using python program. Microsoft and IBM developed WAV Format. WAV doesn't compress the original audio [31].

2. Splitting Audio for Certain Verses

Holy Quran recitations audio data is further split into various groups of verses to study the correlation between reciters for one or more verses. Splitting verses is very important step because the acoustic rhythm is most likely to reveal when the verses are short with short breaks between verses.

3. Remove Silence

Some recitations have a silence period at the beginning and end of the audio file. Using python and Audacity code, all the silence periods were removed at the beginning and at the end of verses for each reciter to get more accurate analysis result.

4. Select Rate

Holy Quran recitations are recorded using different sampling rates like 44 kHz and 22 kHz. Sample rate represents how many samples are recorded per second. Using Librosa, we select 22 kHz as sample rate for all holy Quran recitations audios in this study, which enables analysis that is more accurate.

5. Add Annotation (label)

Each recitation audio raw data is labeled with chapter name, verse number and reciter name. Labeling process is accomplished using python tools.

6. Convert Audio into Visual Representations

There are many visual representations for audio such as waveform, spectral plot, and spectrogram. Figure 3 describes the data conversion steps.

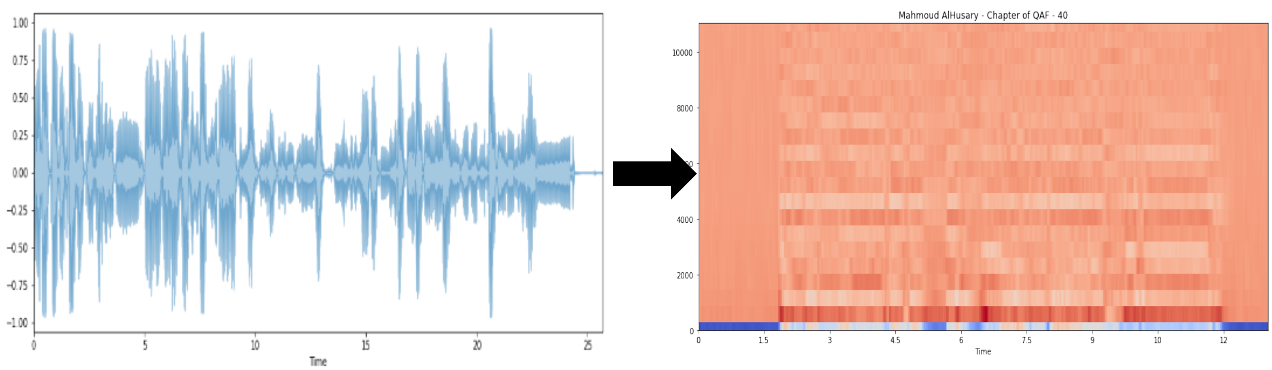


Fig. 3: Data conversion steps

3.3 Feature Extraction

The audio of the holy Quran recitations contains a lot of important information. For this study, we need to extract the characteristics of the recitations for each reciter. This feature is used to prove the acoustic miracle of holy Quran, given that the recitations belong to different reciters, the reciters have different nationality, ages and dialects and then to show how the recitations maintain strong acoustic relationship. Thus, the efficiency of this extraction is vital for the purpose of our study. In this work, the features are extracted using several techniques for the best parametric representation of acoustic signals. Signals features are classified into three main categories: time, frequency and time-frequency domain features [31].

In our study, we focus on time, frequency and intensity features of the recitation signals, where recitation has a lot of information. The major task is to determine this information. Feature extraction phase is the most important and vital in each audio analysis.

In this work, Mel-Frequency Cepstral Coefficients (MFCCs) [32] features are used, since it is found that this feature provides the best parametric representation of acoustic audio signals. As we mentioned, there are various features that can be extracted from the collected holy Quran recitations. However, we only focused on extracting MFCCs, where MFCCs are considered the most important features in signals similarity. Then we use MFCCs to show the correlation strength and the pattern between reciters recitation.

MFCCs features are a common method and widely used to extract features from audio signal. MFCCs are commonly used in audio similarity, speech recognition systems, sound similitude measures and emotion recognition systems. Its features capture the timbral/textural aspects of sound. MFCCs converts a voice signal into several frame and represent it as 2D diagram. MFCCs is frame level feature similarity, which extracted the signals features at the level of individual frames.

Mel Frequency Cepstral Coefficient has been computed using the following steps:

1. Pre-Emphasis

To improve the efficiency of the spectral analysis of the signal the pre-emphasis filter is used. It emphasizes the higher frequencies. Its purpose is to balance the spectrum of voice sounds that have a steep roll-off in the high-frequency region.

2. Framing and Windowing

The essential processing technique for audio is framing. Framing is necessary to collect stable acoustic characteristics and to avoid information loss between frames. This technique fragments the original recitation audio into short period of time [33] (frame) with length range (0-40 ms) for overlapping and framing. Short periods of time (in the range of 10 ms) enable more accurate analysis of the temporal characteristics of recitation audios. We used periods of 25 ms to obtain accurate spectral resolution.

Reducing spectral leakage in recitation windowing audio is a fundamental processing technique; this is achieved by decreasing the amplitude at the beginning and end of each block.

There are several windowing techniques such as Hanning, Flat Top and others. For 95 percent of cases Hanning window function works well [33]. Framing and windowing visual representation are shows in Figure 4.

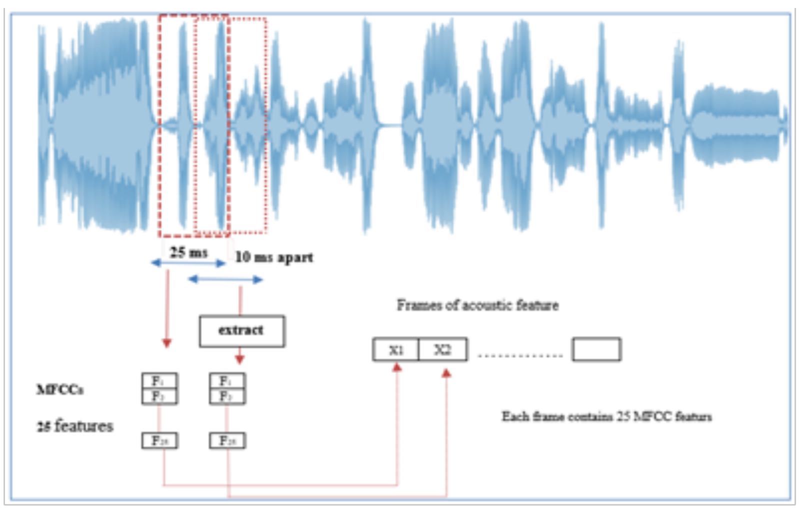


Fig. 4: Visual representation for framing and windowing

3. Fast Fourier Transform (FFT)

In this step, MFCC applying FFT for every frame acquired from the Hamming windowing, FFT converts signal form the time domain to the frequancy domain. Applying FFT improves the signal observation characteristics [34].

4. Mel Filter Bank

The spectrum that we obtained using Fourier transformed signal has a wide range of frequencies. Therefore, we need to pass the spectrum to Mel filter bank, which consists of a set of band-pass filters. Mel is a unit of measure based on the human ears perceived frequency. In my analysis, the Mel filter bank contains a group of 25 triangular filters. Using log scale enables humans to sense loudness on audio signals in lieu of linear scale. The approximation of Mel from physical frequency can be expressed as:

$$f_{Mel} = 2595 \log_{10}\left(1 + \frac{f}{700}\right) \quad (1)$$

Where, f_{Mel} is the frequency Mel and f is the frequency (Hz).

5. Discrete Cosine Transform (DCT)

The latest step is to acquire the MFCCs by representing the Mel spectrum in the time domain. The series of coefficients are called acoustic vectors. therefore, each input recitations signal is converted into an acoustic vector sequence. We can express DCT via the following formula,

$$C(n) = \sum_{K=i}^{N} \cos\left[n * (k - 0.5) * \left(\frac{\pi}{N}\right)\right] E_K \quad (2)$$

where N is the number of Mel spectrum coefficients, E_K is the output of filter bank and $C(n)$ is the final MFCC coefficients.

- ***Delta-delta MFCCs Features***

Delta-delta MFCC [35] features are a common method for extracting information of the second derivatives of the signal. Differentiation is used twice in the delta-delta MFCC feature. Delta-delta MFCC features provide pure aid over instantaneous features. Delta-delta MFCC is used in convergence. Delta-delta MFCC, is correspondingly.

$$\Delta\Delta k = \Delta k - \Delta k - 1 \quad (3)$$

Where $\Delta k = fk - fk - 1$ (delta feature). Specifically, for a feature fk, at time-instant k.

- ***Details of MFCCs Extraction***

Computing MFCC feature vectors for an entire verse recitation piece typically proceeds several tens of thousands individual MFCC feature vectors. For example, a 2 min recitation audio sampled at 22,000KHz. Applying to this verse recitation a MFCC frame-level feature extractor with a frame size of 512 samples produces more than 80,000 feature vectors to describe it. Eq. 4 determines the number of frames for such audio.

$$Nf = .4 * 22000 \text{ samples/s} = 88000 \text{ samples} \quad (4)$$

Then used statistical summarization method to summarize all resulting feature vectors.

3.4 Feature Selection

In our study, we proposed a statistics approach by analyzing the the recitation audio features, all of fetures that extracted as shown in Table 3. Feature selection used to reduce data and create accurate data models.

Our proposed statistical approach to build a consolidated description of the MFCCs features of recitation signals piece, where we depend on the statistical summarization of MFCCs to analyzing the relation between the recitations audios features. The proposed approach was created through concatenating (1) the mean of each of the MFCCs features and divide it by its variance using cepstral mean and variance normalization (CMVN) [36], (2) the mean of each delta MFCCs over all frames. In our study, we extract the MFCCs features by different number of frame lengths, where fine grain values of frame are chosen**.**

Table 3: The recitation audio features.

Feature ID	**Feature Name**
1	Mean of the MFCCs for 25 frame
2	Mean of the delta-deltas MFCCs for 25 frame
3	Mean of the MFCCs for 35 frame
4	Mean of the delta-deltas MFCCs for 35 frame
5	Mean of the MFCCs for 40 frame
6	Mean of the delta-deltas MFCCs for 40 frame

3.5 Similarity Measurement Method

3.5.1 Correlation Coefficients Matrix

In this method, the correlation is determined after extraction MFCCs features for each reciter, where the correlation coefficients used as similarity principle in our work. Correlation coefficient is a numeral measurement of a certain type of correlation, which implies a statistical relationship between variables. The correlation coefficients values from 1 to -1. The following table (Table 4) depicts the correlation value strength.

Table 4: Correlation value strength description.

Correlation Strength	**Correlation value**
Complete Positive Correlation (CPC)	1
Strong Positive Correlation (SPC)	0.9, 0.7
Moderate positive correlation (MPC)	0.69, 0.4

Weak positive correlation (WPC)	0.39, 0.1
No Correlation (Zero) (NC)	0
Moderate Negative correlation (MNC)	-0.1, -0.5
Strong Negative Correlation (SNC)	-0.51, -0.9
Complete Negative Correlation (CNC)	- 1

3.5.2 Euclidean Distance

Euclidean distance (ED) [32] is a metric used to calculate signals similarity between the MFCC's features. We compute the Euclidean distance between each reader's recitations of verses in the three selected chapters of holy Quran. The shorter the Euclidean distance, the higher is the MFCC's similarity among the recitations. The Euclidean distance is defined by [32]:

$$d(x, y) = \sqrt{\sum_{j=1}^{k} \left(x_j - y_j\right)^2} \tag{5}$$

Where x is the MFCCs features of verse recitation of reader1, and y is the MFCCs features of verse recitation of reader2 [37]. We measure the distance between all readers on each verse in holy Quran chapters. The Euclidean distance scale between 0 and the selected maximum possible distance value between MFCCs. The following table (Table 5) depicts the **Ed value** similarity**.**

Table 5: Ed similarity value strength description.

Ed similarity	**Ed value**	
	Mean MFCC	**Deltadelta MFCC**
Complete similarity (CS)	0, 0.1	0, 2
Strong simil+633arity (SS)	0.2, 0.4	3, 4
Moderate similarity (MS)	0.5, 0.9	5, 9
No similarity (NS)	1	10

4 Results

In the experiments, we used three Meccan chapters of the holy Quran #50, #53 and #113 with popular seven readers. All recitations are read by the narration of Hafs An Asim. We carried out our experiments for 785 verses audio. The experiments were used to investigate the work hypothesis, namely the acoustic miracles in the holy Quran. Recitations audio features are extracted using the MFCCs feature extraction technique. We also used different similarity measurement methods to build our statistical learning approach.

MFCCs feature extracted by different number of frames 25, 35 and 40 for each verse recitation by all readers. We used two features such as: the mean of MFCCs coefficients features and the mean of delta-delta MFCCs features with various frames size. The 40 frames represent the fine grain to extract recitation features.

4.1. Results for Correlation Coefficients Matrix

In this method, we study and analyze the evaluation of the MFCC coefficients features by the correlation coefficients matrix analysis of the holy Quran acoustic features. The correlation tests have been made using mean of MFCC coefficients features of the recitations acoustic features to obtain the correlation strength based on three chapters of holy Quran; chapter of Qaf, AlNajm and AlFalaq between seven reciters. To achieve more pitch information for recitations signal, we used the mean of 40 MFCC acoustic coefficients.

As we mentioned in previous chapters, the main pillar of acoustic miracles are the holy Quran words, where if anyone reads the holy Quran verses with Tajweed rules, then there will be acoustic rhythm patterns which are produced by the very nature of the words and their correlation within one verse or across several verses, which may constitute one acoustic cluster. In the holy Quran, there are acoustic clusters because of its word characteristic and its Tajweed rules.

4.1.1. Correlation Coefficients Analysis (verse by verse cluster1)

In this section, we used the mean of MFCC coefficients to find the acoustic correlation coefficients strength between reciters. In this ideation, the acoustic correlation coefficients strength depends on each verse individually (cluster 1). For example, the correlation strength on verse #6 from chapter #50 between whole reciters. Figure 5 illustrates the correlation matrix of sample of verse recitation. The light color indicates a positive correlation; the dark color indicates a negative correlation.

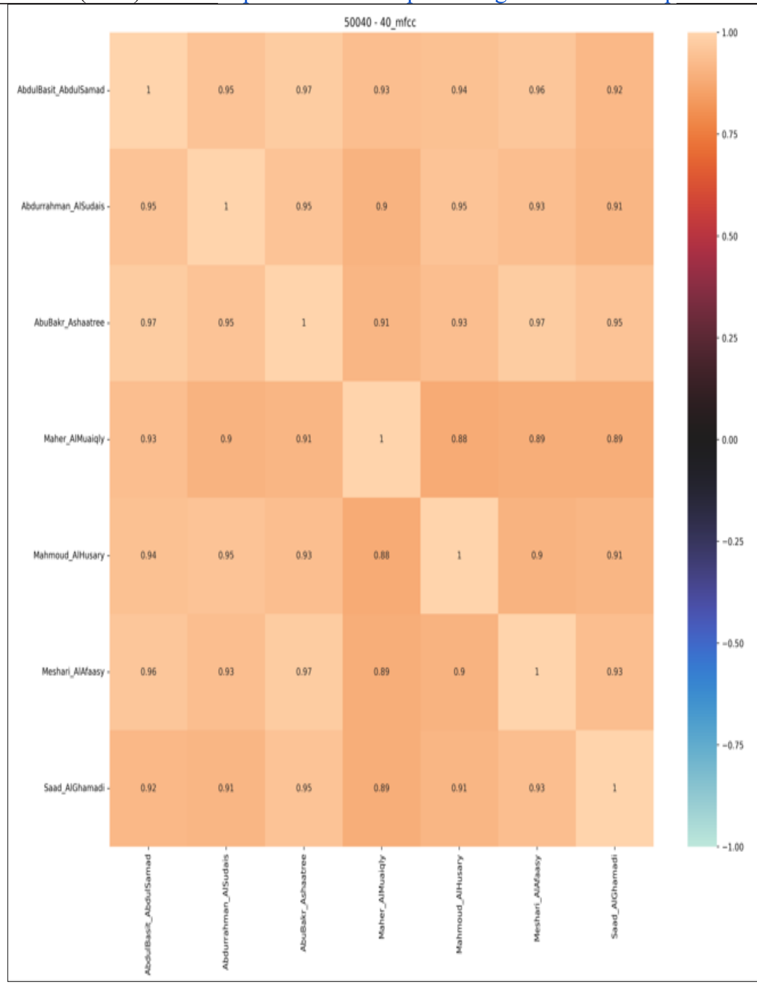


Fig. 5: The correlation matrix between registers in chapter#50- verse 40.

Table 6 presents the average and the variance of the correlation coefficients of all reciters for the selected chapters. The correlation test was made among all reciters by each verse individually (cluster1) for all selected chapters. In this observation, the acoustic correlation coefficients were strong positive correlation between reciters, on the chapters #50, #53 and #113. The analysis show a strong acoustic rhythm correlation between reciters, when they read same verse (verse has same words). This correlation is attributed the sound of the words and letters of the holy Quran itself rather than the skills or the pitch characteristics of the reciters.

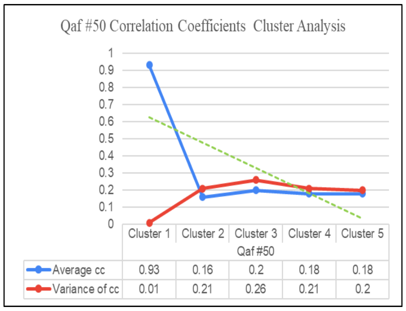
Table 6: Average and variance of the correlation coefficients of all reciters by each verse on chapters.

Reciters	Chapters	Average of CC (cluster1)	Variance of CC (cluster1)	Correlation strength
AbuBakr Ashaatree vs Abdurrahman AlSudais vs Saad AlGhamadi vs AbdulBasit AbdulSamad vs Maher AlMuaiqly vs Mahmoud AlHusary vs Meshari AlAfaasy	Qaf #50	0.93	0.01	SPC
	Al-Najm #53	0.94	0.01	SPC
	Al-Falaq #113	0.90	0.006	SPC

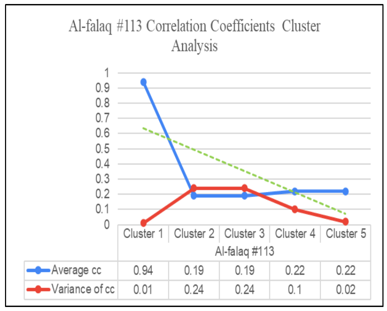
4.1.2. Correlation Coefficients Matrix Cluster Analysis

In this section, we used MFCC coefficients to find the acoustic correlation coefficients matrix cluster analysis between reciters by different clusters indexes. In this ideation, the acoustic correlation coefficients strength depends on building clusters of verse. We built 5 clusters, cluster2 contain 2 indexes (2 verses vs 2 verses for all readers), cluster3 contains 3 indexes (3 verses vs 3 verses for all readers), cluster4 contains 4 indexes (4 verses vs 4 verses for all readers) and cluster 5 contains 5 indexes (5 verses vs 5 verses for all readers).

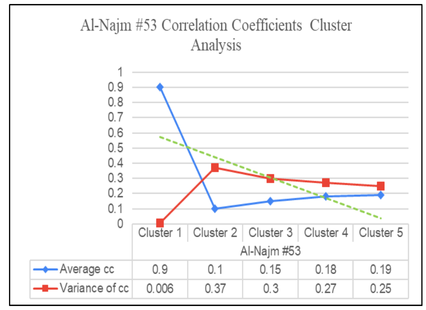
In this observation, the correlation strength was positive correlation in clustering (cluster2- cluster 5), on the chapters #50, #53 and #113 but the correlation strength is weak. Figure 6 shows the linear correlation among clusters for each chapter (#50, #53, #113), it's a negative correlation.



(b) #50 correlation coefficients cluster analysis



(b) #113 correlation coefficients cluster analysis



c) #53 correlation coefficients cluster analysis

Fig. 6: Linear Correlation among clusters (a), (c) and (d).

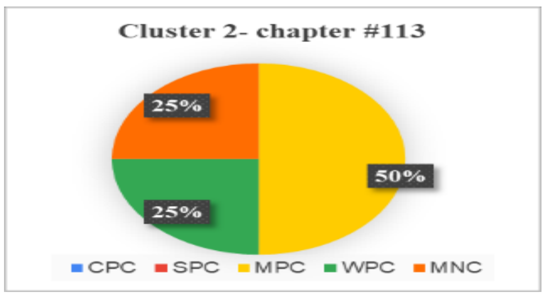


Fig. 7: Correlation coefficients strength for chapter #113

It seems from our analysis that we can prove and show that a strong acoustic correlation between reciters appears when they read individual verse. We observed the existence of acoustic clusters for specific combinations of verses that have a strong correlation, irrespective of the average of the correlation coefficients for the whole chapter. Figures 7, 8 and 9 represent the present of each acoustic cluster with complete, strong, moderate and weak positive correlation strength.

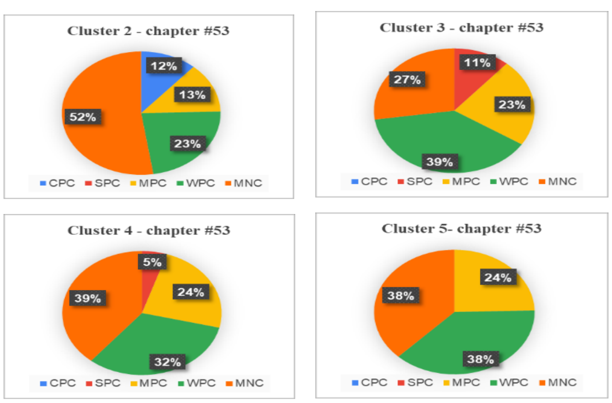


Fig. 8: Correlation coefficients strength for chapter #53 Cluster 2

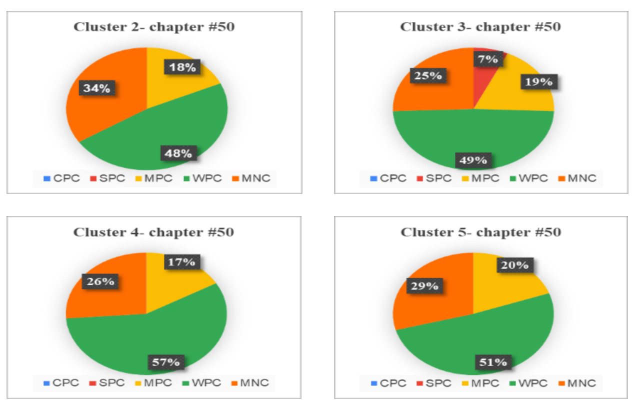


Fig. 9: Correlation coefficients strength for chapter #50 Cluster 2

For example, in chapter #53 cluster2 it turns out that there is an acoustic unit between specific verses; (53,54) and (54,55) clusters have a complete positive correlation. Then in cluster3, the verses relation

is expanded to because 3 indexes per reciter; strong positive correlations appear among (53,54,55) verses with an average of 0.79 to indicate that is a strong acoustic unit among these verses. Figure 10 presents the correlation matrix.

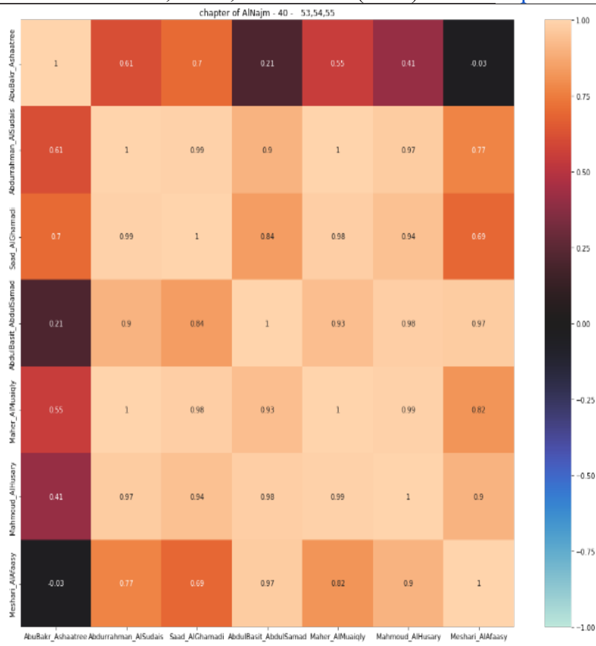


Fig. 10: The correlation matrix between different verses recitation samples of chapter#53 on cluster 2 verse (53,54,55,56).

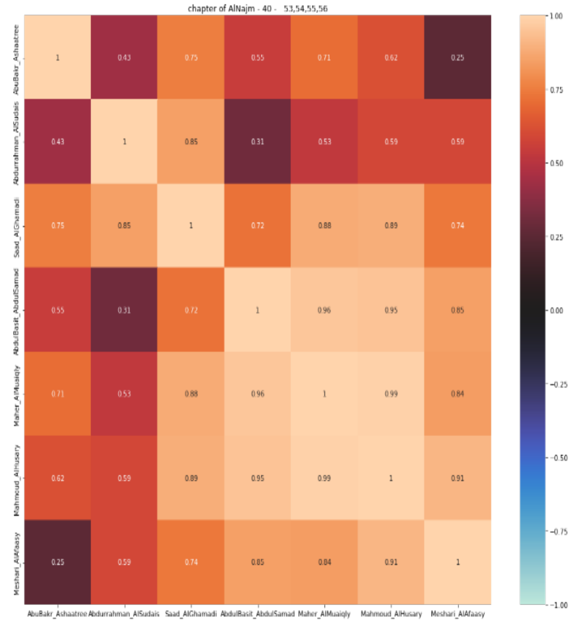


Fig. 11: The correlation matrix between different verses recitation samples of chapter#53 on cluster 3 verse (53,54,55,56).

The 4th cluster, the verses relation is expanded to because 4 indexes per reader; strong positive correlations appear among (53,54,55,56) verses with an average of 0.71 to indicate that is a strong acoustic unit among these verses**.** Figure 11 presents the correlation matrix.

The last cluster with 5 indexes, indicate that when the indexes of cluster be 5 verses; the correlation among (53,54,55,56,57) moderate positive correlations with an average of 0.61 to indicate that there is acoustic unit among these verses, but the correlation value began to decline. The analysis of the acoustic features of the holy Quran indicates the existence of acoustic cluster units, where groups of 2, 3, or 4 verses exhibit strong and moderate correlation. The previous example is based on the following verses from Chapter Al-Najm: ﴿And He destroyed the Overthrown Cities (of Sodom and Gomorrah (53) So that (ruins unknown) have covered them up (54) Then which of the gifts of thy Lord, (O man,) wilt thou dispute about? (55)This is a Warner, of the (series of) Warners of old! (56) The (Judgment) ever approaching draws nigh (57)﴾ (Surah AlNajm #53-57).

In our hypothesis, we assumed these acoustic cluster unit appeared due to the Quranic words, meanings, Harakat, commas and the mechanism of readings as its mentioned on related research such as [38, 39, 40].

And the pronunciation exits of the letter of Quran words have an acoustic miracle, thus the recitation of the holy Quran is characterized by beauty and touching the heart. This acoustic pattern appeared because of the MFCCs feature representing the frequency and amplitude for each recitation pitch characteristic. Furthermore, holy Quran revealed to Muhammad ﷺ in aural, the acoustic tone and rhythm of recitation remained the same way to this time because the acoustic miracle its origin depend on the word in verses and not related to whom read it.

To investigate the acoustic cluster unit in more detail we must work with scientists who specialize in the sciences of the Quran semantic miracles. Since this study is conducted on Chapters from the first period of revelation (Meccan), we believe that a further study on chapters from the Medina chapters is necessary.

4.2. Euclidean Distance Similarity Measure

To illustrate that a pattern between reciters using three chapters, we used MFCCs cepstral coefficient feature (mean MFCCs and deltadelta MFCCs using 40 frame) by Euclidean distance similarity measure and to prove the correlation coefficient measure results. Table 5 (shown in Sec. 3.5.2). illustrated the ED similarity strength after calculating the maximum value for each feature. The maximum value for MFCCs mean feature is 1 and for deltadelta MFCCs mean feature is 10.

4.2.1 ED Similarity Analysis Verse by Verse Cluster1

In this section, we used MFCC coefficients mean and deltadelta MFCC mean features to evidence the acoustic rhythm between reciters by ED similarity measurement. In this ideation, the acoustic rhythm similarity depends on each verse individually (cluster 1). For example, the similarity strength among recitations of verse #60 from chapter #53 between whole reciters.

Tables 7, 8 and 9 show the evaluation MFCCs features (Mean of MFCCs, deltadelta MFCCs) using average of ED between the readers for chapters #50, #53 and #113 and determine the similarity strength between acoustic rhythm for each reciter.

Table 7: Evaluation the average of ED using MFCCs features among 7 reciters on chapter#53.

Evaluation MFCCs features using Euclidean distance. (Chapter #53 – Al-Najm)				
Reciters	**ED (Mean of MFCC)**	**ED similarity**	**ED (deltadelta MFCC)**	**ED similarity**
AbuBakr Ashaatree	0.4	SS	2.35	SS
Abdurrahman AlSudais	0.55	MS	4.26	SS
Saad AlGhamadi	0.37	SS	2.27	SS
AbdulBasit AbdulSamad	0.33	SS	1.64	CS
Maher AlMuaiqly	0.29	SS	1.65	CS
Mahmoud AlHusary	0.28	SS	1.73	CS
Meshari AlAfaasy	0.4	SS	2.74	SS

Table 8: Evaluation the average of ED using MFCCs features among 7 reciters on chapter#50.

Evaluation MFCCs features using Euclidean distance. (Chapter #50 – Qaf)				
Reciters	**ED (Mean of MFCC)**	**ED similarity**	**ED (deltadelta MFCC)**	**ED similarity**
AbuBakr Ashaatree	0.37	SS	3.65	SS
Abdurrahman AlSudais	0.56	MS	8.09	MS
Saad AlGhamadi	0.31	SS	6.61	MS
AbdulBasit AbdulSamad	0.31	SS	2.39	SS
Maher AlMuaiqly	0.42	MS	2.3	SS
Mahmoud AlHusary	0.31	SS	4.37	SS
Meshari AlAfaasy	0.44	MS	4.19	SS

Table 9: Evaluation the average of ED using MFCCs features among 7 reciters on chapter#113.

Evaluation MFCCs features using Euclidean distance. (Chapter #113 – Al-Falaq)				
Reciters	**ED (Mean of MFCC)**	**ED similarity**	**ED (deltadelta MFCC)**	**ED similarity**
AbuBakr Ashaatree	0.18	SS	2.35	SS
Abdurrahman AlSudais	0.29	SS	4.26	SS
Saad AlGhamadi	0.15	SS	2.27	SS
AbdulBasit AbdulSamad	0.13	SS	1.64	CS
Maher AlMuaiqly	0.14	SS	1.65	CS
Mahmoud AlHusary	0.13	SS	1.73	CS
Meshari AlAfaasy	0.15	SS	2.74	SS

Tables 7, 8 and 9 evaluate the ED average of MFCCs mean and deltadelta MFCCs mean features for each reciter depending on each verse (cluster1) for the selected chapters. The Ed test was made among whole reciters by each verse individual for all selected chapters.

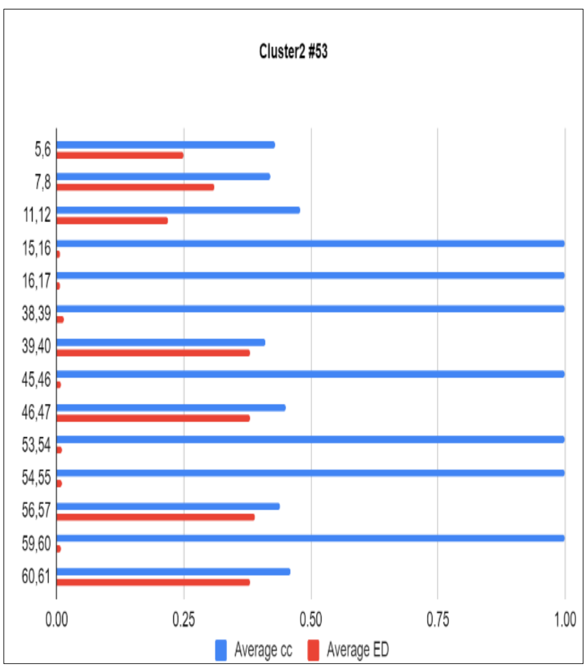
In this observation, the acoustic similarity on chapter #53 by using mean MFCCs were strong similarity for all reader and by using deltadelta MFCCs mean; AbdulBasit AbdulSamad, Maher AlMuaiqly and Mahmoud AlHusary have complete similarity and AbuBakr Ashaatree, Abdurrahman AlSudais, Saad AlGhamadi and Meshari AlAfaasy have strong similarity with others. On chapter #113 by using mean MFCCs were strong similarity for all reader and by using mean of deltadelta MFCCs mean; AbdulBasit AbdulSamad, Maher AlMuaiqly and Mahmoud AlHusary have complete similarity with others and AbuBakr Ashaatree, Abdurrahman AlSudais, Saad AlGhamadi and Meshari AlAfaasy have strong similarity with others. Last, in chapter #50 by using mean MFCCs mean; AbuBakr Ashaatree, Saad AlGhamadi, AbdulBasit AbdulSamad, Maher AlMuaiqly and Mahmoud AlHusary have strong similarity and Abdurrahman AlSudais has moderate similarity with others.

In this observation, the acoustic similarity between reciter on chapters #50, #53 and #113 exhibits high similarity value. It seems from our analysis that we can prove and show that high acoustic rhythm similarity appears between readers when they read same verse. High similarity value is an indication of a miraculous feature of holy Quran words and letters acoustic attributes. It is obvious that the acoustic features of the recited verses are not dependent on the skills of the reciters. The results of this hypothesis emphasize the results that appeared previously using CC measure.

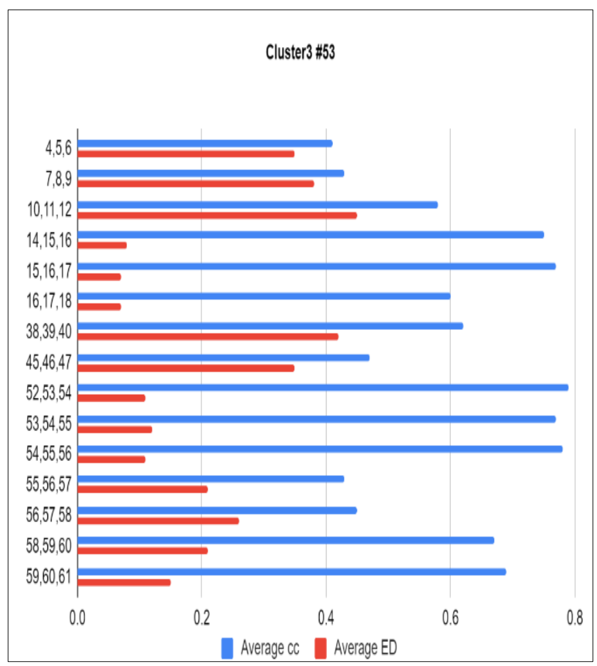
4.2.2. ED Similarity Cluster Analysis

In this section, we used MFCC coefficients to find the acoustic ED similarity between reciters by different clusters indexes. In this ideation, the acoustic ED similarity strength depends on building clusters of verse. In this observation, we attempt to assert the results obtained from the Correlation Coefficients matrix cluster analysis. We use correlation coefficients matrix cluster analysis between readers in chapters #50, #53 and #113 with different indexes. The figures 12, 13 and 14 show the relation between CC and ED matrix cluster analysis between readers in chapter #53 by different cluster indexes where for CC the CPC is 1 and for ED the CS is 0.

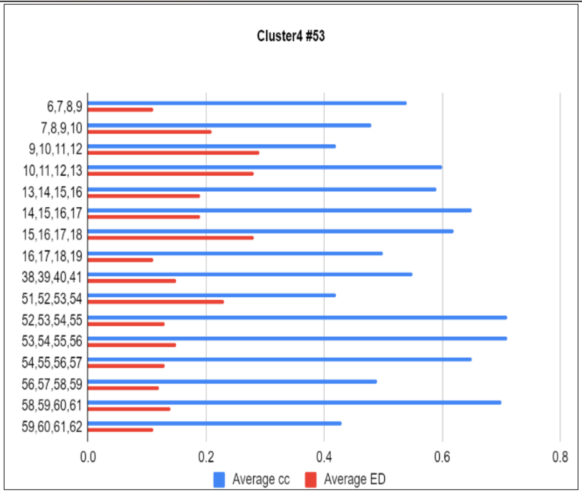
Based on the figures 12,13 and 14, the comparison results between CC and ED in clusters analysis show convergent result in all chapters #50, #53 and #113. The comparison result proves the acoustic cluster hypothesis in this thesis, where there are clusters for acoustic rhythm in holy Quran because of the holy Quran miracle. The same indexes cluster have approximately the same relative strength in CC and ED. The acoustic rhythm cluster appears among reciters because the holy Quran reads by rules, the miracle in the arrangement of Quran verses words, the navigation between verses, words meaning, and the length and shortness of the verse.



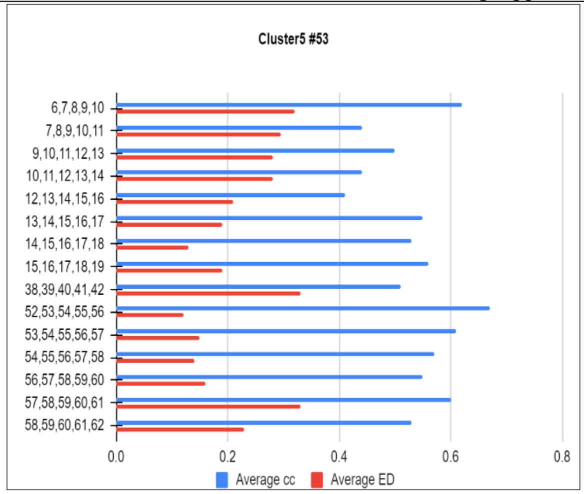
(a) Cluster2



(b) Cluster3

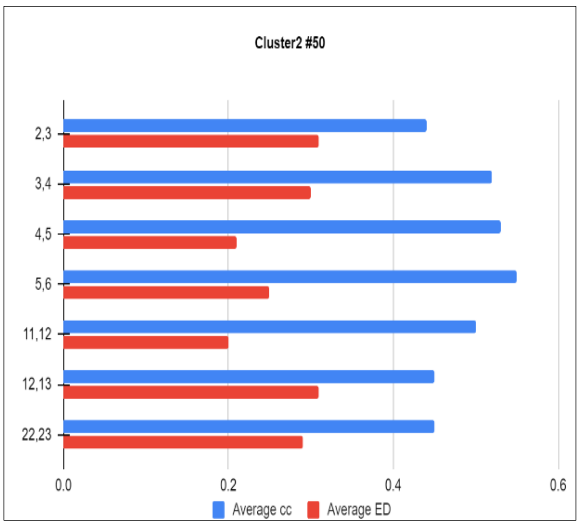


(c) Cluster4

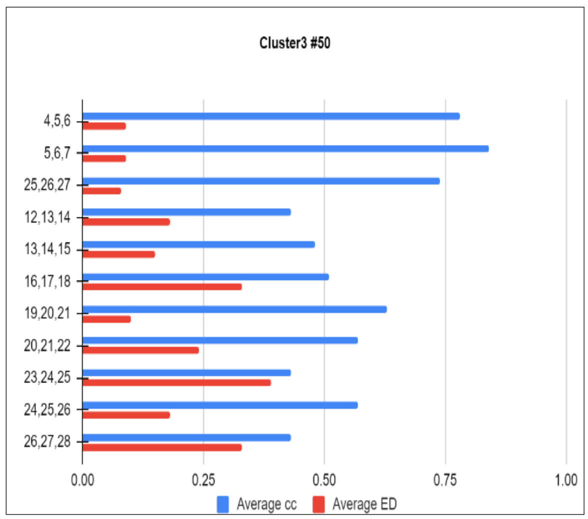


(d) Cluster5

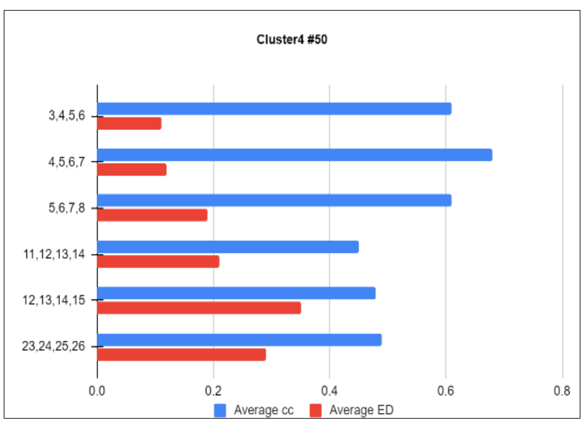
Fig. 12: The relation between CC and ED matrix cluster analysis between readers **in** chapter #53 by different cluster indexes.



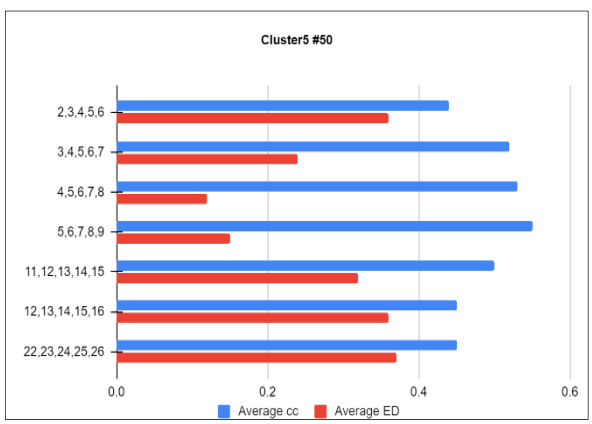
(a) Cluster2



(b) Cluster3

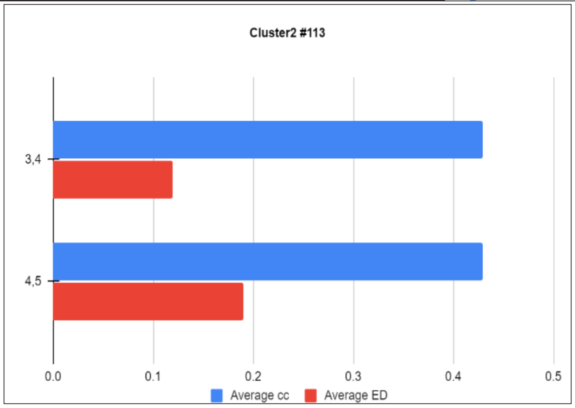


(c) Cluster4

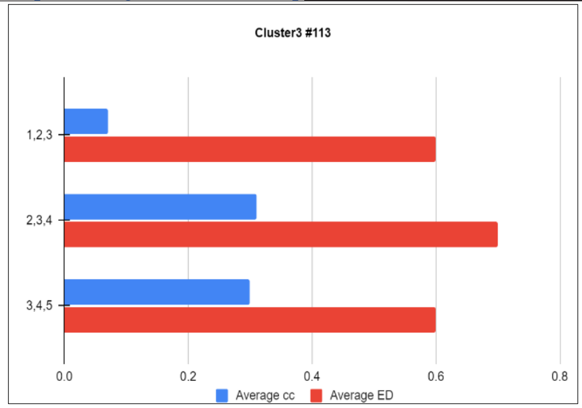


(d) Cluster5

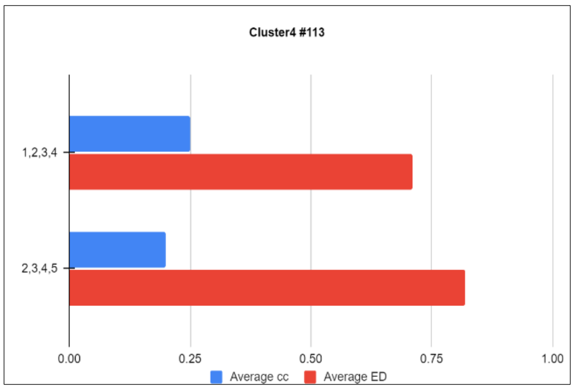
Fig. 13: The relation between CC and ED matrix cluster analysis between readers **in** chapter #50 by different cluster indexes.



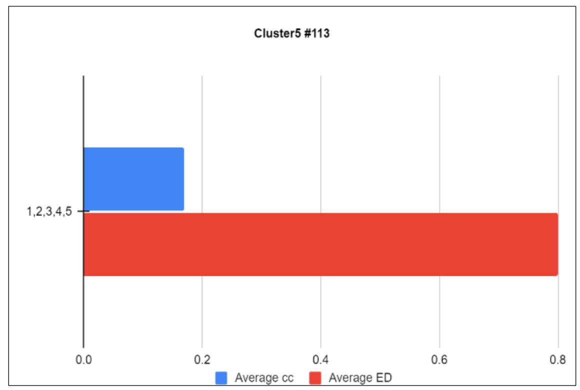
(a) Cluster2



(b) Cluster3



(c) Cluster4



(d) Cluster5

Fig. 14: The relation between CC and ED matrix cluster analysis between readers **in** chapter #113 by different cluster indexes.

5 Conclusions

In this paper, the feature of the holy Quran recitations audio is extracted to evidence the acoustic miracles in the Holy Quran using MFCCs audio features extraction. Acoustic rhythm correlation was made between seven reciters by three chapters (Surah) in the Quran. Our study reveals that the recitation of the Holy Quran exhibits certain common features irrespective of the reciters. A comparison was made between two similarity measurement methods correlation coefficients and Euclidean distance.

Acoustic miracles evidence is proved by several results, which were summarized in several points:

- The holy Quran words are the main pillar of acoustic miracles, where if anyone reads the holy Quran verses with Tajweed rules there will be acoustic rhythm patterns.
- There is no variance in the recitation of the verses of holy Quran for various reciters.
- Strong correlation between MFCCs spectral coefficients mean feature for each verse's recitation through of seven reciters for three chapters of holy Quran.
- High Euclidean distance similarity between MFCCs spectral coefficients mean feature and deltadelta MFCCs mean feature for each verse's recitation through of seven reciters for three chapters of holy Quran.
- The acoustic miracles in the Holy Quran brighten up in the individual verse through the seven reciters.
- Holy Quran acoustic cluster appear after building specific set of verses recitation by the seven readers.

In future, we plan to extend our statistical evidence approach of the acoustic miracles in the holy Quran using several audio features. Applying different audio features extraction to the same dataset to extract features and compare results such as spectral centroid and chroma features.

6 Recommendations

The research recommends the study and analysis of more audio features to assert the acoustic miracles in Holy Quran. Furthermore, more research needs to be conducted to detect acoustic clusters in the Quran and to investigate the correlation between acoustic clusters and semantic cluster of Quran verses.

Conflict of interest

The authors declare that there is no conflict regarding the publication of this paper.

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